US ARMY CORPS
OF ENGINEERS
New England District

Contract No. DACW33-01-D-0004
Delivery Order No. 02
January 2003

Final Survey Report

WINTER 2002 PHYSICAL OCEANOGRAPHIC DATA COLLECTION SURVEY

RHODE ISLAND REGION LONG-TERM DREDGED MATERIAL DISPOSAL SITE EVALUATION PROJECT

FINAL

Winter 2002 Physical Oceanographic Data Collection Survey

Rhode Island Region
Long-Term Dredged Material Disposal Site Evaluation Project

Contract Number DACW33-01-D-0004
Delivery Order No. 02

to

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ACRONYMS

ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
CTD	conductivity- temperature-depth
Corps	U.S. Army Corps of Engineers
DGPS	Differential Global Positioning System
EPA	U.S. Environmental Protection Agency
FFT	Fast Fourier Transform
Hz	hertz
KHz	kilohertz
IMLM	Iterative Maximum Likelihood Method
m	meter
MHz	megahertz
MLLW	Mean Lower Low Water
mm/s	millimeter per second
m/s	meter per second
NOAA	National Oceanic and Atmospheric Administration
NRCC	Northeast Regional Climate Center
NTU	nephelometric turbidity units
OBS	optical back scatter
OSI	Ocean Surveys, Inc.
RDI	RD Instruments
RI Disposal Study	Rhode Island Region Long-Term Dredged Material Disposal Site Evaluation Project
USCG	U.S. Coast Guard

1.0 INTRODUCTION

During the period of March 8 – June 10, 2002, Ocean Surveys, Inc. (OSI) conducted an oceanographic field investigation in the waters of Rhode Island Sound. Tide, current, wave, turbidity, and temperature data were acquired at a single station located in candidate disposal site 69b. This work, conducted under contract to Battelle Memorial Institute, was undertaken to support of the Rhode Island Region Long-Term Dredged Material Disposal Site Evaluation Project. The purpose of the Winter 2002 physical oceanographic data collection was to characterize tidal and non-tidal currents throughout the water column at Site 69b in late winter, when disposal events are most likely to be occurring, when there is a highly mixed water column, and when there is a high likelihood of winter storm events. An overview of the methods and equipment used in the collection of physical oceanographic data during the Winter 2002 study are presented in this report.

2.0 FIELD PROGRAM

Upon receiving approval from Battelle to begin work, OSI mobilized and prepared for instrument deployment. However, weather conditions around the deployment date were poor, and the OSI field team was forced to wait for calmer sea conditions. On 8 March 2002 the winds abated and the OSI field team installed the oceanographic instrumentation along with a surface marker buoy at Site 69b.

Approximately one week after deploying the instrumentation, OSI was notified by manufacturer RD Instruments (RDI) that they had discovered that newly installed firmware in the current profiler/wave gauge by RDI had a flaw that might prevent data collection. Upon receiving the news, OSI mobilized to recover and check the questionable instrument. High winds and rough seas prevailed for almost two weeks, thwarting any efforts to recover the instrument. After recovery attempts on 25 and 28 March that were aborted due to rough seas, the instruments were recovered on 29 March. The current profiler/wave gauge was found not to be working due to the firmware problem. The field team installed an RDI supplied firmware patch to the Acoustic Doppler Current Profiler (ADCP), again conducted a “dry” deployment to ensure the instrument was functioning, and redeployed it. All other instruments had functioned as intended and their data were downloaded and returned to the office for processing. Due to the aforementioned instrument problems, 29 March was deemed the new “start date” and the subsequent servicing and recovery schedule was adjusted accordingly.

Following the 29 March redeployment, data collection proceeded smoothly, with 100% data recovery for the remainder of the program. Poor weather delayed servicing trips by up to a week at a time, but each subsequent trip to the project site was successful. The mid-deployment servicing was accomplished on 6 May 2002 and final instrument recovery was completed on 10 June 2002. Instrument and guard buoy locations are presented in Table 1.

Table 1. Instrument Mount and Marker Buoy Locations.

Station	Station Location RI State Plane (ft) & Latitude/Longitude NAD83				Water Depth MLLW	
	Easting	Northing	Latitude	Longitude	feet	meters
Instruments	361821	55682	41° 14' 9.93"	71°22' 38.41"	125	38.1
Marker Buoy	361967	55635	41° 14' 9.42"	71°22' 36.50"	125	38.1

3.0 METHODS

3.1 Survey Vessel, Navigation, and Horizontal Control

Field operations were conducted by a two-man OSI field team consisting of a Senior Physical Oceanographer and a Field Electronics Engineer. Work was conducted from the *R/V West Cove*, a 42-foot coastal research vessel outfitted for mooring installation and Conductivity-Temperature-Depth (CTD) profiling.

A Trimble 4000 Differential Global Positioning System (DGPS) interfaced with Coastal Oceanographic's PC-based software package, HYPACK Max, was used for survey vessel navigation and positioning. The global positioning system consists of 24 earth-orbiting satellites which broadcast radio signals to the earth's surface. These signals are used by the GPS receiver to calculate its position based on the signal's Doppler shift. Three or more satellite signals are required to accurately calculate the receiver's position. Differential correctors, used to increase vessel position accuracy to ± 1 meter (m), were received via a radio link to a United States Coast Guard (USCG) beacon transmitter. The geodetic positions derived from the DGPS system were converted to the Rhode Island State Plane Coordinate system (NAD83) for survey operations and preparation of final products.

The HYPACK navigation system was used for positioning and placement of all *in situ* instruments. This navigation system receives geodetic position data every second and converts these data into x-y grid coordinates in the specified plane coordinate system. The incoming data are recorded and processed in real time by the HYPACK computer. The vessel position, within a previously constructed project drawing of the survey area, is displayed on a video monitor to aid the boat operator in navigation. This system provides a highly accurate visual representation of survey vessel location in real time.

3.2 Moored Instruments

All *in situ* instruments were deployed on a single seafloor mount custom built by OSI (Figure 1). The use of just one instrument mooring served to maximize the potential for data correlation between sensors, as all data were collected from the same point. Furthermore, OSI's single mooring design served to minimize onsite time during instrument deployment, servicing, and recovery trips.

Figure 1. OSI's Custom Seafloor Mount.

As a precaution, OSI deployed a Surface Marker Buoy System to protect the installed bottom mounted instrumentation. This surface marker buoy was necessary because of commercial fishing in the area. During processing of the EPA-required side scan sonar data to create a mosaic for Site 69b, drag marks left by commercial fishing were observed. The surface marker consisted of a lighted yellow Gilman Corporation Softlite Ionomer Foam NavAid buoy moored to the sea floor by a 900-pound anchor system and chain. The Gilman Buoy rides approximately 7 feet above the water surface, with a flashing light at a height of 6 feet, and is approximately 6 feet in diameter. Made out of Gilman's patented ionomer foam, the buoy is extremely rugged and can survive heavy open sea conditions. The buoy provided the visual lighting and radar warning necessary to keep commercial fishermen at a safe distance from the instrumentation. The sample rate, range, accuracy, and precision of moored instruments are given in Table 2.

3.2.1 ADCP

Horizontal and vertical currents throughout the water column from near surface to near bottom were measured using an *in situ* RDI 600 kilohertz (kHz) ADCP. The ADCP was deployed on the sea floor in an upward looking configuration. The current meter recorded velocity data at 15-minute intervals using an ensemble of 120 samples, and a vertical resolution of 1.0 m.

Table 2. Instrument Configuration.

Instrument	Sensors	Sensor Depth	Sampling Rate	Range	Accuracy	Precision
ADCP 600kHz	Current Profile	1-m bins	15 min interval 120 pings per ensemble 6 sec per ping	0.001 – 20 m/s	+/-0.25%	0.001 m/s
ADCP 600kHz	Waves (from orbital velocities)	38.1 m	1 hr interval 10min. burst 1200 pings per burst 0.5 sec per ping	0.001 – 20 m/s	+/-0.25%	0.001 m/s
ADV	3-D Current Velocity Vector	37.1 m	15 min interval 150 sec per burst 300 samples per burst 0.5 sec per sample	0.001 – 5 m/s	+/- 0.5%	0.0001 m/s
Water Level Recorder	Pressure	38.1 m	15min interval 160 sec per burst 128 samples per burst 1.25 sec per sample	0 – 900 psia	0.015%	16 bit
YSI Turbidity	Turbidity	37. 1m	15 min interval 15 samples per burst	0 – 1000 NTU	+/- 5% or 2 NTU (which ever is greater)	0.1 NTU

The ADCP contains four acoustic transducers that each produce a 600 kHz acoustic signal (Figure 2). Each transducer is angled 20° off-center and evenly spaced around the head of the instrument. The instrument sends out acoustic pulses (pings), listens to the acoustic backscatter reflect off particles throughout the water and measures the Doppler shift of the return signal. The motion of the particles can then be calculated. Range gating is used to divide the signal into a series of vertical measurement volumes or depth bins. Data from a minimum of three transducers are used by the instrument to calculate a three-dimensional vector representing current speed and direction at each depth bin.

Each ping takes less than one second, and after a preset number of pings (an ensemble), the results are averaged over the length of the ensemble, grouped together within the specified depth range (depth bin), and stored digitally by the ADCP. Depth bins are not simple numerical averages of the current in a discreet portion of the water column. Rather, they represent a weighted average of current velocities across overlapping sections of the water column (Figure 3). The overlap between adjacent depth cells results in a correlation between the cells of about 15 percent (%). Data collected from the center of the depth cell are more heavily weighted in the average than data collected at the fringes of the cell because depth cells are more sensitive to currents at the center of the cell than at the edges.

Figure 2. ADCP with Acoustic Locating Pinger.

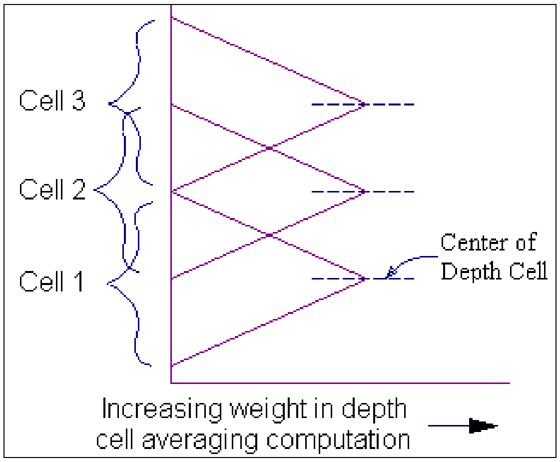


Figure 3. Depth Cell Weight Function (Courtesy of RDI, 1996).

The overlapping nature of the depth bins, combined with the weighted averaging between the bins, results in more accurate data.

During processing, the *in situ* ADCP current data were converted from binary to ASCII format, using specialized software provided by the manufacturer. The resulting ASCII data were then processed and vector-averaged using custom OSI Matlab processing routines and Microsoft Excel. A table of the ASCII data was generated to show current speed and direction in the horizontal plane and vertical current speed at 1.0-meter vertical increments above the sea floor over the deployment period. Table 3 outlines the distance from the ADCP and water depth for each bin. The data are presented as ASCII listings on the enclosed CD-ROM.

Table 3. ADCP Bin Depths.

Bin #	Distance from ADCP		Water Depth at Center of Bin	
	meters	feet	meters	feet
1	2	6.6	35.6	116.9
2	3	9.8	34.6	113.6
3	4	13.1	33.6	110.3
4	5	16.4	32.6	107.0
5	6	19.7	31.6	103.8
6	7	23.0	30.6	100.5
7	8	26.2	29.6	97.2
8	9	29.5	28.6	93.9
9	10	32.8	27.6	90.6
10	11	36.1	26.6	87.4
11	12	39.4	25.6	84.1
12	13	42.7	24.6	80.8
13	14	45.9	23.6	77.5
14	15	49.2	22.6	74.2
15	16	52.5	21.6	71.0
16	17	55.8	20.6	67.7
17	18	59.1	19.6	64.4
18	19	62.3	18.6	61.1
19	20	65.6	17.6	57.8
20	21	68.9	16.6	54.5
21	22	72.2	15.6	51.3
22	23	75.5	14.6	48.0
23	24	78.7	13.6	44.7
24	25	82.0	12.6	41.4
25	26	85.3	11.6	38.1
26	27	88.6	10.6	34.9
27	28	91.9	9.6	31.6
28	29	95.1	8.6	28.3
29	30	98.4	7.6	25.0
30	31	101.7	6.6	21.7
31	32	105.0	5.6	18.5
32	33	108.3	4.6	15.2
33	34	111.5	3.6	11.9
34	35	114.8	2.6	8.6

3.2.2 ADCP Waves

In addition to recording currents, the ADCP was also configured to record the directional wave field present within the project site. The instrument was fitted with a pressure sensor and RDI's custom firmware to allow for the collection of directional wave spectra. The profiling ability of the ADCP (its use of four beams, and discrete depth bins) allows the instrument to essentially function as an array of sensors. The ADCP wave gauge is able to measure wave orbital velocities throughout the water column yielding wave field measurements. Furthermore, because orbital velocities from higher frequency waves attenuate more quickly with increasing depth, the ADCP is able to resolve much higher frequency waves than traditional single point wave gauges. In addition to recording the orbital velocities and wave pressure record, the ADCP applies a third technique to further quantify the wave field. Each of the four beams from the ADCP echo ranges the sea surface to determine wave height over the instrument. This "surface track" method is particularly useful in resolving higher frequency waves.

The wave gauge records significant wave height, period, and direction; directional spectra, and non-directional wave-height spectra. Directional wave data were recorded in 10-minute bursts every hour for the duration of the 2-month deployment. Wave height and directional spectra data are presented in Hertz (Hz), which equals the square root of the wave energy density spectrum. RDI recommends using a minimum period threshold of 2.95 seconds for non-directional waves, and 4.98 seconds for directional waves.

The ADCP wave data were processed using RDI's WaveMon software, version 2.0a. Wave data collection consisted of 1200 samples collected at 2 Hz for 10-minute bursts every hour. Wave spectra were calculated using a Fast Fourier Transform (FFT), which utilized the first 1024 samples of each 10-minute burst. In order to keep the wave power in the peak of a Pearson-Moscowitz wave spectrum, a Bartlett window was applied to the time series data prior to performing the FFT (RDI, 2001). Wave height spectra were calculated from both the vertical velocity data from depth cells (26-34) and from the surface track data, which recorded the surface elevation from each of the four transducers. Directional wave data were calculated from the orbital velocities from 5 depth cells (26, 28, 30, 32, & 34) by each of the 4 transducers. Since the orbital velocities measured near the surface were used to calculate the directional wave spectra, the wave parameters were calculated based on the velocity spectra data. These parameters included the significant wave height, peak period, peak direction, maximum wave height, and mean period.

Non-directional wave spectra were broken down into 256 frequency divisions from 0 to 1 Hz for both the velocity wave height spectrum and the surface track wave height spectrum. To calculate the directional wave spectra, WaveMon software utilizes the Iterative Maximum Likelihood Method (IMLM). Data were run through three iterations to maintain most of the energy back towards the peak of the wave spectrum. The directional wave spectra were broken down into 128 frequency divisions from 0 to 1 Hz and processed into 90 evenly spaced 4° pie slices. Wave spectrum data calculated at frequencies higher than 0.33 Hz (beyond the accuracy of the ADCP) were considered unreliable due to mathematical noise created through the FFT. These data were not considered in calculating the wave parameters. The wave parameter data were saved as

ASCII listings on CD-ROM. Velocity and surface track wave height spectra data, as well as directional spectra data, were saved as ASCII listed on CD-ROM.

3.2.3 Acoustic Doppler Velocimeter (ADV)

The current velocities at 1 m above the seafloor were recorded using a SonTek 5 megahertz (MHz) ADV single point current velocity instrument. The SonTek ADV is a versatile, high-precision instrument which uses acoustic Doppler technology to measure three-dimensional flow in a small sampling volume located a fixed distance (18 centimeters (cm)) from the probe (Figure 4). With no zero offset, the ADV can be used to measure flow velocities from less than 1 millimeter per second (mm/s) to over 5 meters per second (m/s). The ADV was deployed on a bottom mounted mooring in an upward looking configuration. The probe was positioned such that the sensor would measure the three-dimensional velocity structure 1 m above the sea floor. The unit collected 300 samples at 2 Hz once every 15 minutes.

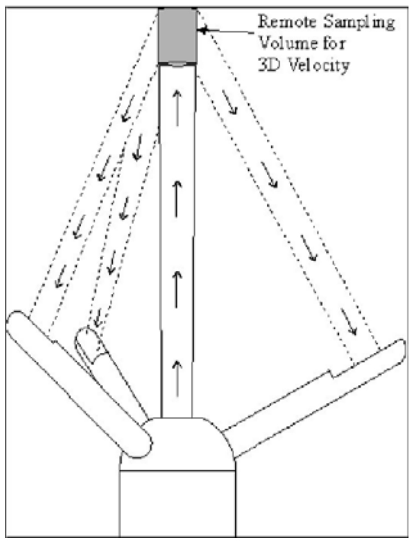


Figure 4. ADV Sampling Volume.

The recorded data was processed using Sontek, Microsoft Excel, and OSI custom Matlab processing routines. Current magnitude and direction were calculated from the raw data collected in east, north and vertical current vectors. The data were presented as ASCII time series listings of current magnitude and direction as well as east, north, and vertical current velocity vectors.

3.2.4 ParoScientific Digiquartz Tide Gauge

Surface tidal elevation measurements were taken using OSI's Precision Water Level Recorder, which incorporates a ParoScientific Digiquartz Sensor. This unit was used because of its extreme stability, accuracy, and ability to resolve very small changes in depth even though the unit was deployed in approximately 125 feet of water. The ParoScientific Digiquartz system recorded pressure data using a burst of 128 samples over a 2-minute and 40-second period every 15 minutes. Tide gauge data were corrected for fluctuations in barometric pressure based on recorded data at Newport, RI (KUUU) acquired through the Northeast Regional Climatic Center (NRCC). The Micro-Tide recorder was referenced to Mean Lower Low Water (MLLW) by comparing the recorded data with tide gauge data collected from the National Oceanographic and Atmospheric Administration (NOAA) tide gauge installed at Newport, RI (#8452660). The mean water level over the course of the survey period was computed for both the OSI Micro-Tide recorder data and the NOAA tide gauge. A direct comparison was made between the two values. The OSI data was adjusted by this difference to produce water levels referenced to MLLW. The water elevation data are available as ASCII listings on CD-ROM.

3.2.5 Turbidity Measurement

Turbidity was measured at 1 m above the sea floor using primary and backup turbidity systems. The primary turbidity system used was the YSI Model 6600 multi-parameter water quality datalogger outfitted with YSI's 6026 wiped turbidity sensor. The YSI turbidity sensor employs a wiper that sweeps fouling agents from sensor optical surfaces prior to measurement. Long-term deployments with this sensor as part of YSI's submersible, multi-parameter water quality monitoring systems, have demonstrated constant measurement accuracy and stability. Known advantages to this system include: (1) inhibition of both active and passive fouling; (2) nominal power consumption (ideal for extended deployments); (3) removal of bubbles which result from out-gassing of ambient water; and, (4) sensor is mounted in the bulkhead of sonde with no interface hardware exposed to the environment. The YSI 6600 Multi-parameter unit recorded turbidity values (in nephelometric turbidity units (NTU)) at 15-minute intervals.

The backup turbidity system was a standard D&A Instrument Company (D&A) Optical Back Scatter (OBS) 3A Turbidity Sensor attached and controlled by the SonTek ADV Unit. This unit was also set to record turbidity data (in NTU) at 15-minute intervals. Both sensors were set at 1 meter above the sea floor. Turbidity data are presented as ASCII listings on CD-ROM.

3.3 Conductivity-Temperature-Depth (CTD) Vertical Profiling

Conductivity and temperature data throughout the water column were collected using a Sea-Bird Electronics, Inc. Model SBE 19 SeaCat Profiler. The SeaCat Profiler is a self-powered, self-contained micro processing unit capable of collecting temperature, conductivity, and depth data at a rate of two scans per second. Data are internally processed, corrected, and recorded in solid-state memory and can later be transferred via an RS-232 port to a computer where the operator can view the data and archive it for future processing. The recorded conductivity and temperature data were used to calculate salinity and density.

Operationally, the SeaCat was lowered over the side of the vessel into the water where it was allowed to equilibrate with the surrounding water. To collect a cast, the instrument was lowered through the water column to the bottom. Once at the bottom, the SeaCat was held steady, then returned to the surface.

Vertical profile data were collected through four casts during each of the trips to deploy, service, or recover the *in situ* mooring (Table 4). The resultant 16 casts were downloaded to a computer and post-processed using Sea-Bird Electronics CTD Data Acquisition Software, Seasoft version 4.238. The raw data were calibration corrected and reduced to listings of depth versus temperature (° C), salinity (psu), and density. The data are presented as vertical profile plots (Appendix A) and as ASCII listings on CD-ROM.

Table 4. CTD Cast Date, Time and Location.

Station	Date	Time	Station Location			
			RI State Plane (ft) & Latitude/Longitude NAD83			
			Easting	Northing	Latitude	Longitude
1	3/8/02	10:02	361723	55628	71° 22' 39.70"	41° 14' 09.39"
2	3/8/02	10:09	361783	55649	71° 22' 38.91"	41° 14' 09.60"
3	3/8/02	10:15	361839	55687	71° 22' 38.18"	41° 14' 09.98"
4	3/8/02	10:22	361913	55798	71° 22' 37.21"	41° 14' 11.07"
1	3/29/02	17:45	361723	55628	71° 22' 39.70"	41° 14' 09.39"
2	3/29/02	17:35	361783	55649	71° 22' 38.91"	41° 14' 09.60"
3	3/29/02	17:40	361839	55687	71° 22' 38.18"	41° 14' 09.98"
4	3/29/02	17:27	361913	55798	71° 22' 37.21"	41° 14' 11.07"
1	5/6/02	07:00	361723	55628	71° 22' 39.70"	41° 14' 09.39"
2	5/6/02	18:01	361783	55649	71° 22' 38.91"	41° 14' 09.60"
3	5/6/02	18:04	361839	55687	71° 22' 38.18"	41° 14' 09.98"
4	5/6/02	18:10	361913	55798	71° 22' 37.21"	41° 14' 11.07"
1	6/10/02	11:04	361723	55628	71° 22' 39.70"	41° 14' 09.39"
2	6/10/02	11:09	361783	55649	71° 22' 38.91"	41° 14' 09.60"
3	6/10/02	11:14	361839	55687	71° 22' 38.18"	41° 14' 09.98"
4	6/10/02	11:19	361913	55798	71° 22' 37.21"	41° 14' 11.07"

4.0 SUMMARY

Velocity, wave, turbidity, and temperature data were obtained at a station located in proposed disposal site 69b in the waters of Rhode Island Sound in the winter and spring of 2002, in an effort to help characterize typical site conditions. A complete data set was recovered during the period from March 29 through June 10, 2002. Initial deployment began on March 8, but an instrument problem required recovery and redeployment of the instrument array on March 29. As a result, the deployment was extended accordingly. Measurements were made from a single bottom mounted mooring and included water column velocity profiles, surface waves, near-bottom temperature, near-bottom turbidity and a redundant measurement of near-bottom velocity. In addition to the moored measurements, spatial surveys of temperature and salinity variation were performed during the deployment, inspection, and recovery surveys on March 8, March 29, May 6, and June 10. Data return for the spatial surveys and all moored instruments

for the period March 29 through June 10 was 100%. Preliminary review of the data indicates that the data set is adequate to characterize the hydrodynamic environment at Site 69b for the study period.

5.0 REFERENCES

RDI. 1996. *Workhorse Technical Manual*, Version 2.0.

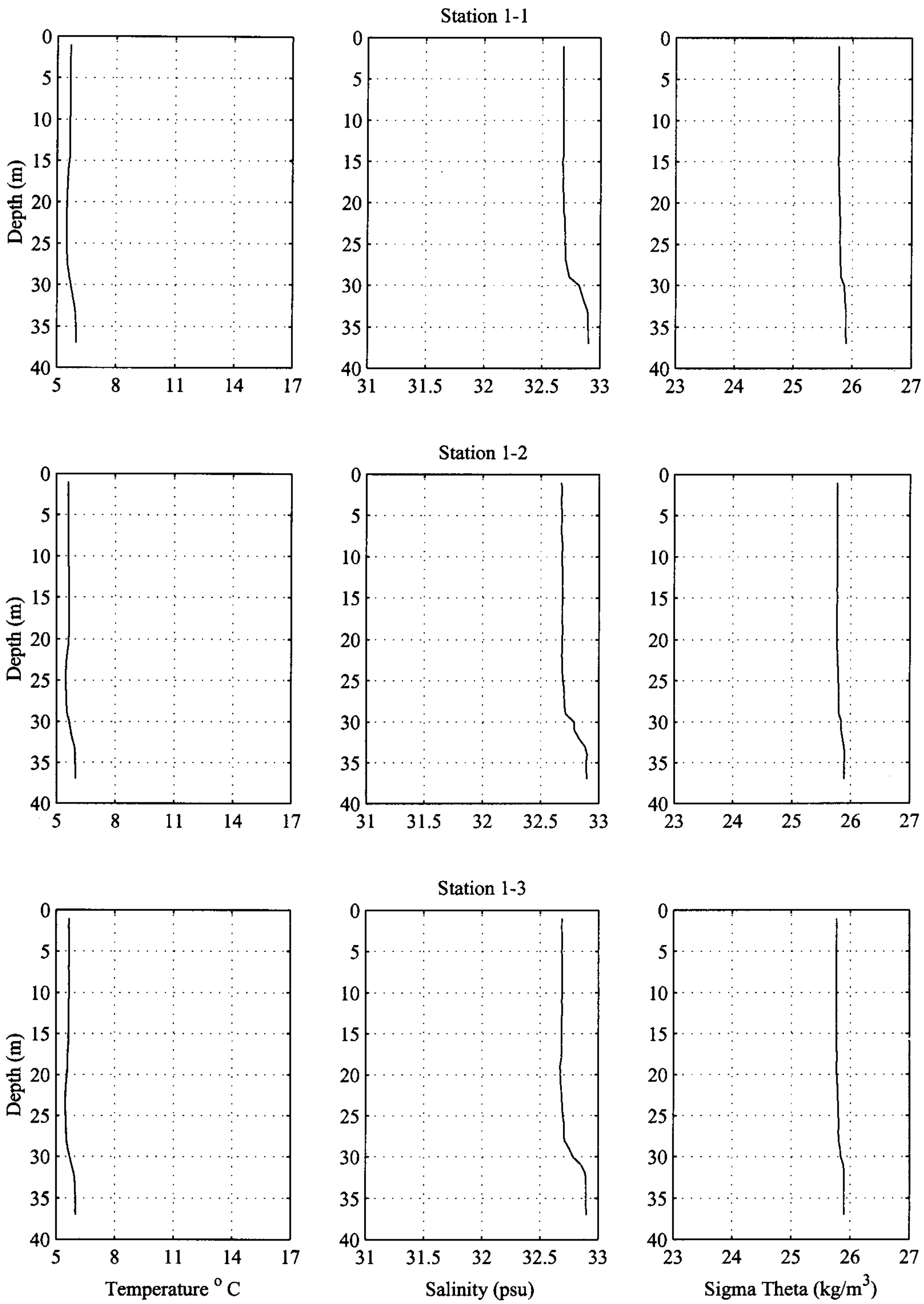
RDI. 2001. *Wave User's Guide*, P/N 957-6148-00, April 2001.

APPENDIX A

CTD Vertical Profiles

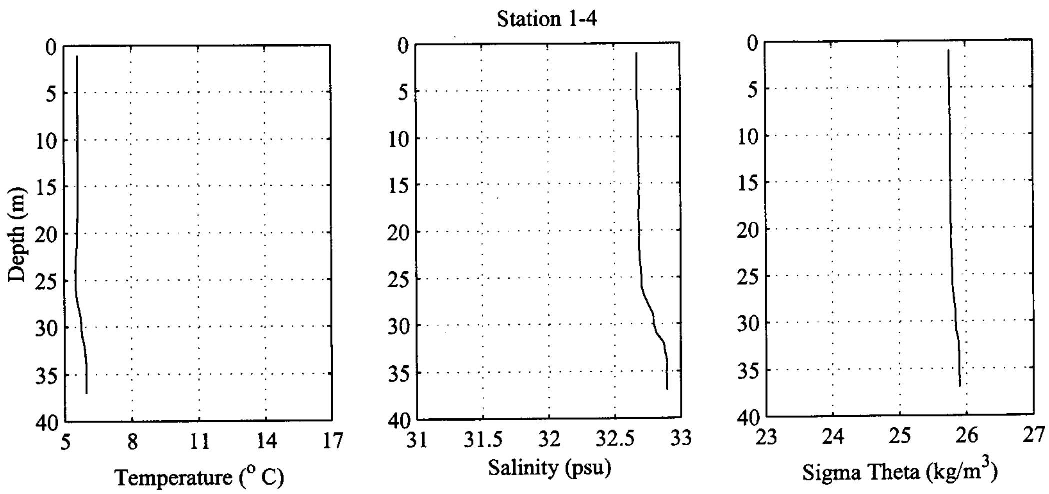
CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
Instrument Installation - 8 March 2002



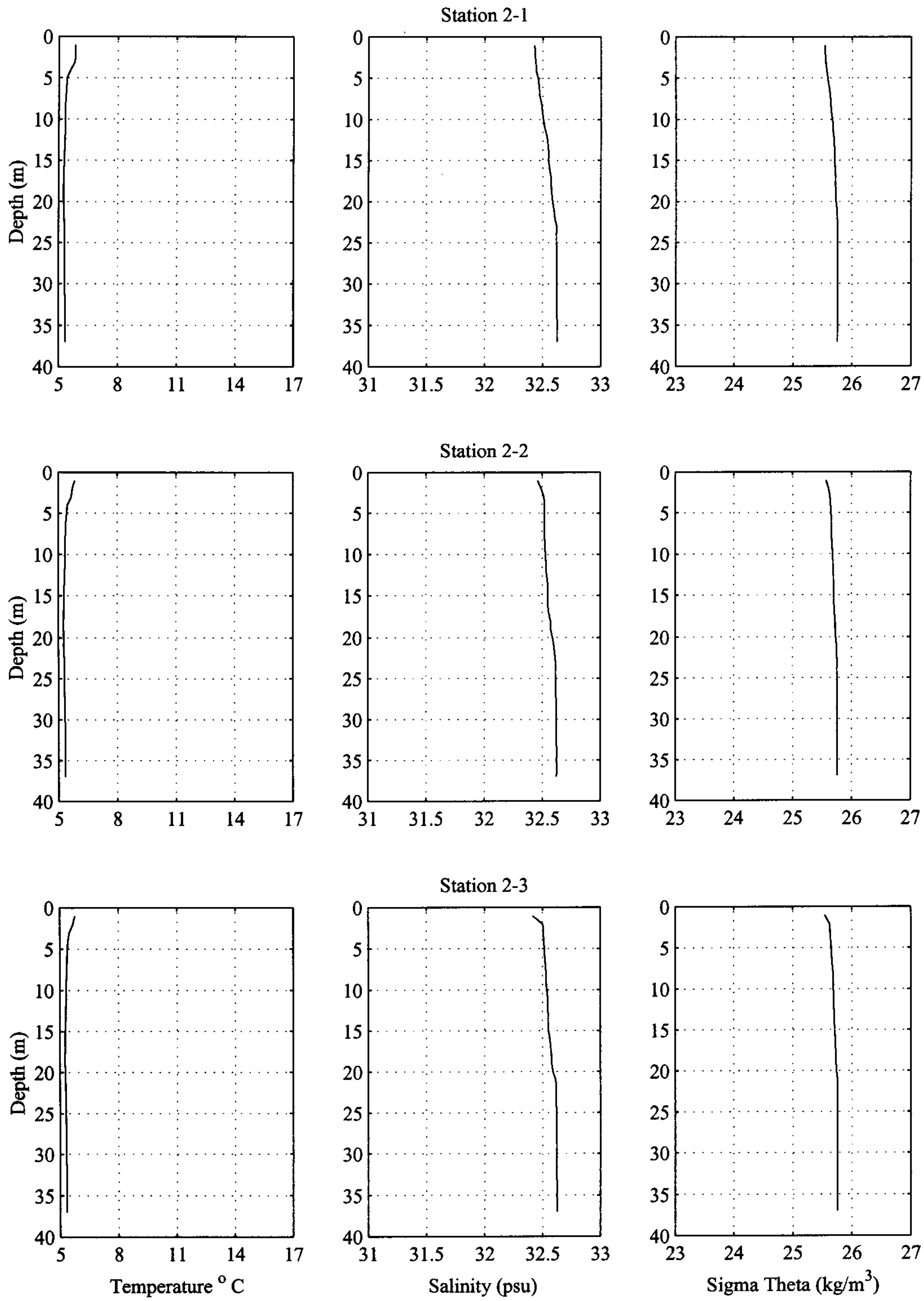
CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
Instrument Installation - 8 March 2002



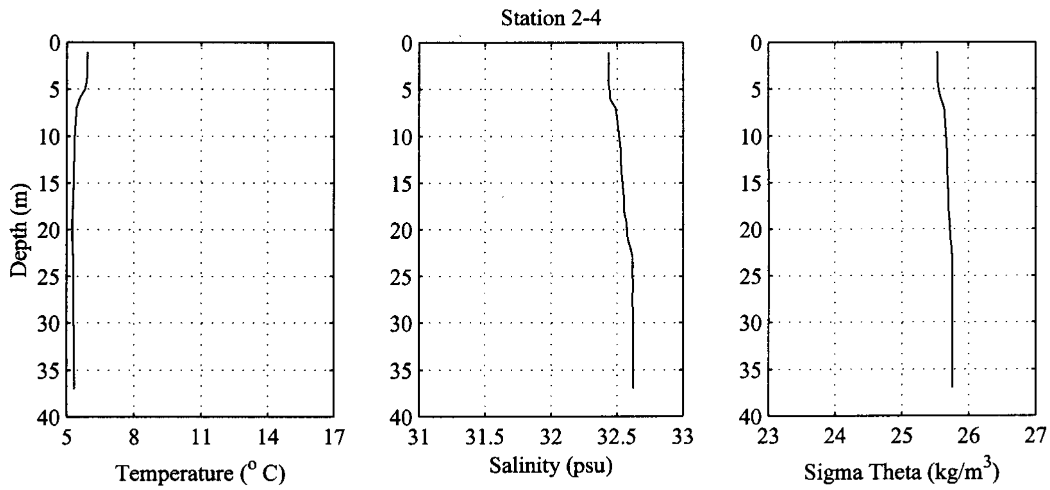
CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
1st Servicing - 29 March 2002



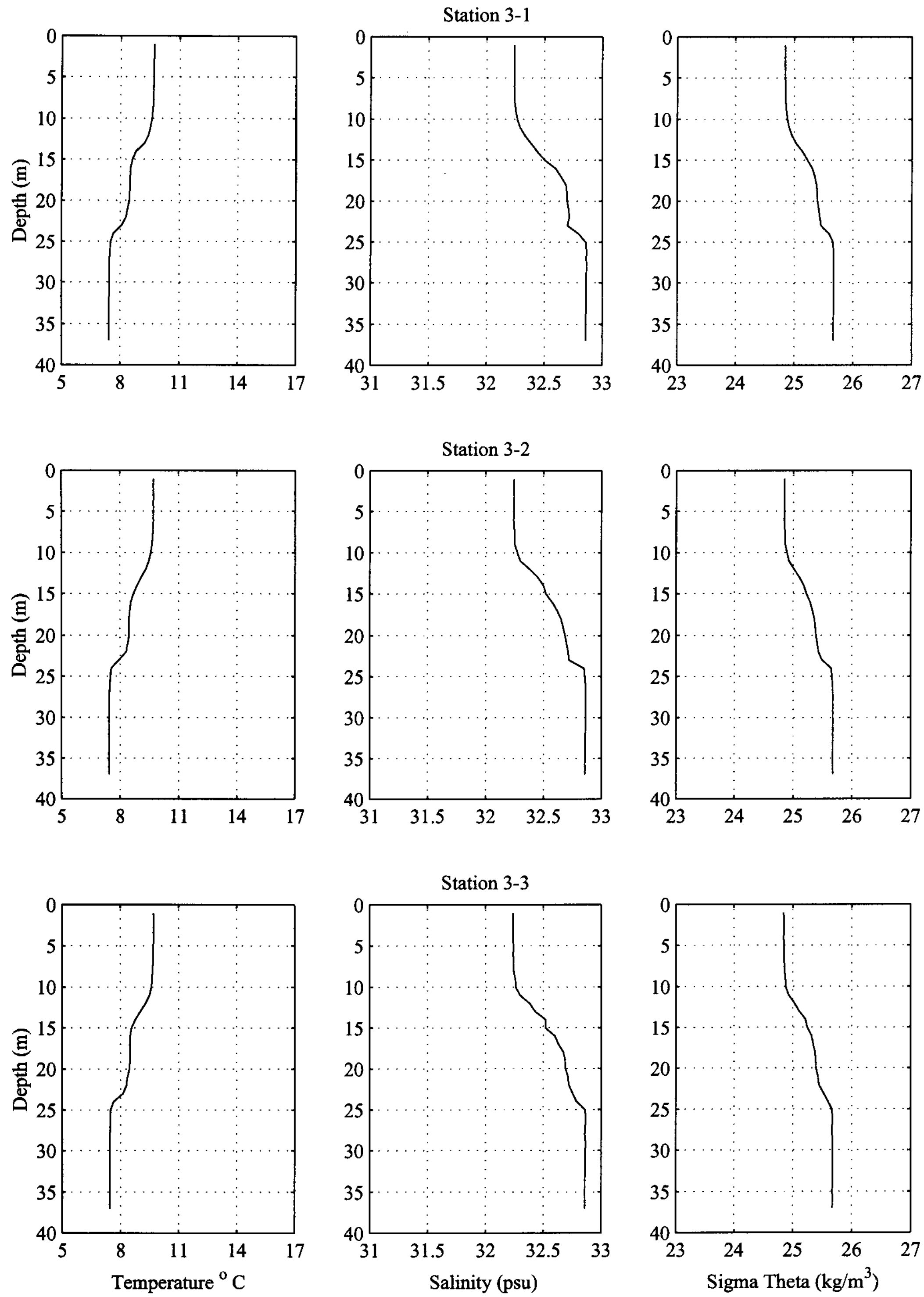
CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
1st Servicing - 29 March 2002



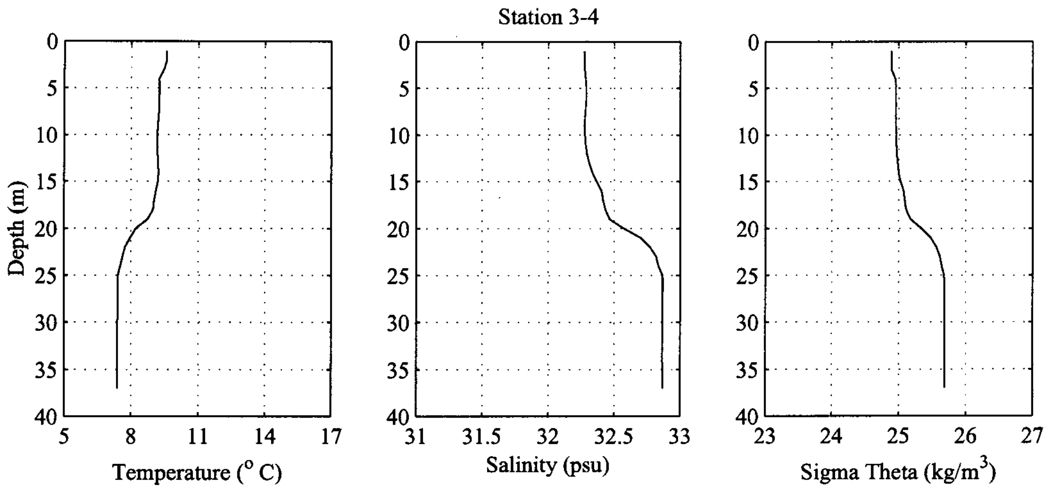
CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
2nd Servicing - 6 May 2002



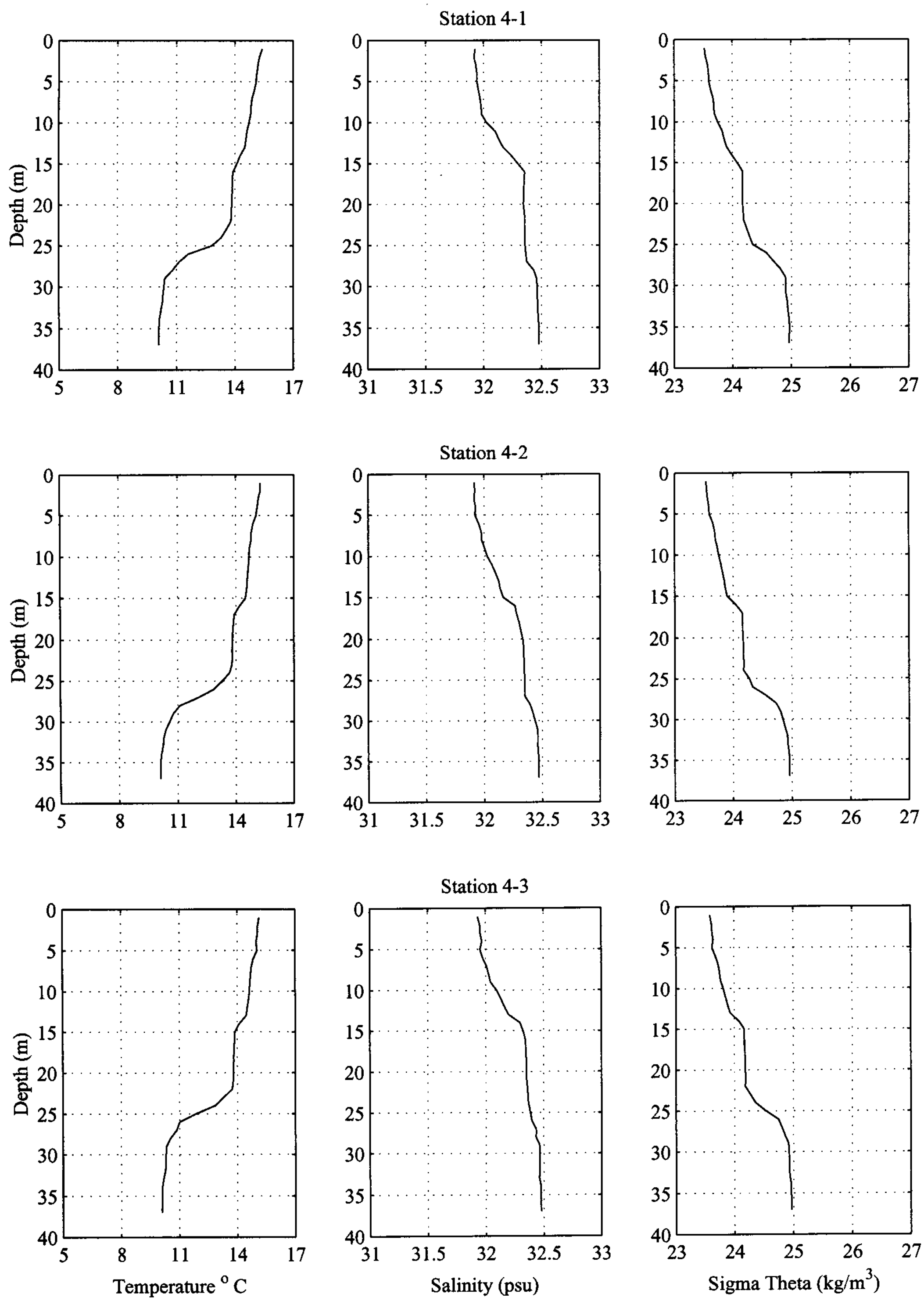
CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
2nd Servicing - 6 May 2002



CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
Instrument Recovery - 10 June 2002



CTD Vertical Profiles

Rhode Island Sound Disposal Site Study
Instrument Recovery - 10 June 2002